Magnetosphere 1: A Different Magnetosphere

Introduction

This lab will use model results to explore how changing parameters of the magnetosphere - dipole strength and dipole tilt - will change or not change the character of the magnetosphere and its interaction with "typical" solar wind conditions at 1 AU.

Before you begin we need to agree on some definitions for regions in the magnetosphere. As a group, define how you would identify the following features using results from simulations:

- the leading edge of the bow shock
- the magnetopause
- the width of the magnetosheath
- the reconnection point (assuming the solar wind IMF is southward)

Be sure that your definitions reference plasma parameters derived from simulation results. Be prepared to discuss these with the whole group.

Driver of the Magnetosphere: The Solar Wind

Before looking at the simulation results directly, compare the idealize solar wind that is used to drive these simulations with the real solar wind. This link is to a table of runs for different dipole strengths.
http://ccmc.gsfc.nasa.gov/support/HSS_2013/dmearth.php
The table not only provides links to the run outputs, but also gives you the run parameters. Notice that the solar wind conditions for all the runs are the same. "Dm" refers to the dipole moment of the Earth.

- What aspect of these solar wind conditions are unrealistic? (Here is a link to the solar wind conditions measured by ACE over the last 7-days http://www.swpc.noaa.gov/ace/MAG_SWEPAM_7d.html)

Identifying Day Side Features of the Magnetosphere

We will start by exploring changes in the dipole strength of the Earth while keeping the relative tilt at 11 degrees. Try opening each run in a different tab or window. You may want to compare one run to another.

- *Start with the "Dm=2.*Dm_earth" run. Select the "View Magnetosphere" link and then click "Update Plot"*
- What parameter is plotted? What units for length are being used?
- Which direction is towards the Sun?
- Can you visually identify the features of the magnetosphere in this image?

Keep this image in a separate window for reference and return to the table.

Try looking at a line plot of some plasma variables.

- *Again choose the "Dm=2.*Dm_earth" run and select the "View Magnetosphere".*
- *Select "Line (1D) from the "Plot Mode" drop down.*
- *In "Choose Quantities", select quantities based on the definitions you came up with in the beginning. (One possible set is "N", "V_x", and "B_z")*
- *In the "Plot Area" section, set:*
  X1 to "0" and X2 to "20"
  Y1, Y2, Z1 and Z2 to "0"
- *Choose "Update Plot"*
- From this line plot can you identify the features of the magnetosphere defined above?
- Does this plot take you directly through the "Nose" of the magnetopause?
- *Constrain the "X" variables a little to get more detail.*

- From this plot identify the position of the bow shock and magnetopause, the position of the reconnection point ("X"- point), the width and maximum density of the magnetosheath.
- How useful are the definitions identified earlier?
- Do these features occur in the order you expect them to be?

Variation in Stand-off Distance with Dipole Strength

Now lets look at the other cases.

- *Click the links for one of the other simulation modes (Suggest that you work from high "Dm" down to low)*
- *On the large shared work space, make a table for the values that you just collected above for all of the runs.*

- What general trends do you see in the results?
- Can you compare the trend in the simulation stand off distance to an estimation from a simple model (for example https://en.wikipedia.org/wiki/Magnetopause#Estimating_the_standoff_distance_to_the_magnetopause)? What would be the best way to plot the values to see if they were consistent with the estimate?
- Are you surprised by any of the simulation results? Which might represent a problem from a space weather point of view?

Tail Effects of Differing Magnetic Field Strengths

First we have to define what we mean by the "magnetotail"

- Discuss in your groups what features you might look for in the tail?
- Again, how do you define these features?

Be prepared to talk about this with the whole group.

Choose one of the features to explore in the tail region and begin to look for it in the simulation results.

- *Start by looking at the X-Z cut plane again. The easiest way to do this is to return to http://ccmc.gsfc.nasa.gov/support/HSS_2013/dmearth.php and open up each page again.*
- *Again click on each run link and choose "View Magnetosphere".*
- *In the "Quantity" Q1 drop down menu choose the appropriate variable to explore.*

- Can you identify the tail feature you are looking for? (You may want to adjust the "Plot Area" using the "X" and "Z" values to zoom in)
- How far down the tail does the feature appear?
- *Again construct a table for the different runs and compare the results.*
- What general trends and surprises do you see?

You may want to use the line plots to investigate these values more carefully.

- How might a simple line plot mislead you?

Different Dipole Tilts

Another variable we can change is the dipole tilt. This page
http://ccmc.gsfc.nasa.gov/support/HSS_2013/tileangle.php
has links to three runs with the dipole tilt at 11 degrees, 45 degrees and 90 degrees.

- *Investigate these first by using the 2D plots of the plasma density.*
- Do the structures we defined in the beginning still make sense?

- Use the definitions and tools we developed above to explore these runs. Make a table of the values ask for above.

Lab 3b: Magnetosphere 2: A Magnetosphere in Different Places

Introduction
This lab will use model results to explore how a the magnetosphere of a planet will vary depending on the distance from the Sun.

Goals:
Students will learn:
- which solar wind parameters affect the global structure of the magnetosphere.
- how these factors change with distance from the Sun.
- how the solar wind parameters impact the magnetosphere.

[Prior to this lab you may want to review the definitions of magnetosphere structures that were developed in Lab 3- Magnetosphere 1]

Before you begin, as a group discuss:
- What are the important drivers and parameters that affect the shape of the magnetosphere?
- How do these vary for planets at different distances from the Sun? *[Review your results for Lab 2- Helio Lab]*
- How do you expect the magnetosphere to change at differing distances from the Sun?
- How might a planetary ionosphere change with differing distances from the Sun?

Magnetospheres at Different Distances
This link is to a table of runs for different dipole strengths.
http://ccmc.gsfc.nasa.gov/support/HSS_2013/11deg.php
The table not only gives links to the run outputs, but also gives you the run parameters. The "Keywords" indicate the simulated distance from the Sun, and the solar wind parameters are given.
- Is the variation in solar wind parameters consistent with what you discussed above?
- Why do the other parameters change?

Now let's look at the specific simulations.
- *Open up all of the simulation links in new tabs and click on "View Magnetosphere" and click "Update Plot".*
- *Use the "Plot Area" settings to adjust the image size. The plot initially displays density. You may have to choose another variable to see the magnetosphere features in all of the runs.*

- Looking over all of the runs, does the magnetosphere change qualitatively in the way you expect it to?
- What qualitative changes do you see?

Quantitative Changes

- Using the “Line(1D)” plots the way you did in the last lab, identify all of the quantities that we identified previously and tabulate them as a function of distance from the sun. The included:
  - on the day side: position of the bow shock and magnetopause, the width and maximum density of the magnetosheath.
  - on the night side: how far away does the current sheet first develop, and what the maximum value of the current in it. (You may want to go back to the 2D slices for this?)
- What general trends do you see in these features?
- Try plotting the magnetopause stand off position as a function of distance from the Sun. Does it fit the functional form you expect? What solar wind variables do you have to account for? [See section 10.3.1 of Vol. I: Plasma Physics of the Local Cosmos]